Naval Submarine Medical Research Laboratory

NSMRL Special Report #06-01 04 May 2006

COMMAND HISTORY
OPNAV 5750-1
FISCAL YEAR 2004

Jerry Lamb, Ph.D., Maria Fitzgerald and Heather Huebner, Editors

Naval Submarine Medical Research Laboratory
Special Report #06-01

Released by:
J. C. DANIEL, CAPT, MC, USN
Commanding Officer
NavSubMedRschLab

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
04-05-2006	SPECIAL	01October2003 - 30September2004

4. TITLE AND SUBTITLE

COMMAND HISTORY OPNAV 5750-1 FISCAL YEAR 2004

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Jerry Lamb, Ph.D.
Maria Fitzgerald
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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

NAVSUBMEDRSCHLAB
Box 900
Groton, CT 06349-5900

8. PERFORMING ORGANIZATION REPORT NUMBER

NSMRL Special Report SR#06-01

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

OPNAV 5750-1

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This is the Command History, OPNAV 5750-1, for the Naval Submarine Medical Research Laboratory for Fiscal Year 2004.

15. SUBJECT TERMS

NSMRL, Command History

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			M. Fitzgerald, Publications Manager
U	U	U	SAR	35	19b. TELEPHONE NUMBER *(Include area code)* (860) 694-2442

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ABSTRACT

This is the Command History, OPNAV 5750-1, for the Naval Submarine Medical Research Laboratory, for Fiscal Year 2004. This FY04 report begins October 1, 2003 and ends September 30, 2004. The previous report SR 04-01 was recorded by calendar year beginning January 1, 2003 and ending December 31, 2003, therefore, some duplication may exist.

ADMINISTRATIVE INFORMATION

This report was approved on May 04, 2006 and assigned Special Report Number 06-01.

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COMMAND HISTORY
Fiscal Year 2004
Part 1

1. Basic Historical Narrative

a. Command Mission

The Naval Submarine Medical Research Laboratory's (NSMRL) mission is to protect the health and enhance the performance of our war fighters through focused submarine, diving, and surface research solutions. Established in World War II, NSMRL was originally responsible for selecting personnel for training at the Submarine School, conducting specialized training in submarine medicine for Hospital Corpsmen and Medical Officers, and researching medical aspects of submarines and diving. Today, NSMRL continues to be the biomedical R&D leader in submarine medicine, health effects of submarine atmosphere constituents, auditory sonar information processing, selection/qualification of submariners, escape and rescue from disabled submarines, diving bioeffects, and hearing conservation technology.

b. Command Staff

Commanding Officer:	CAPT G. A. Higgins, MSC, USN
Executive Officer:	LCDR R. K. LeBlanc, MSC, USN LCDR T. C. Herzig, MSC, USN
Technical Director:	Jerry C. Lamb, Ph.D.

Departments:

Submarine Medicine & Survival Systems	CDR W. G. Horn, MC, USNR
Diving & Environmental Simulation	E. A. Cudahy, Ph.D.
Human Performance	CDR K. S. Wolgemuth, MSC, USN LCDR L. J. Crepeau, MSC, USN
Resources	HMCS(SS) M. J. Napolitano USN

c. Facilities:

(1) Located on the Naval Submarine Base New London, Groton, CT, NSMRL researchers have access to three Attack Submarine Squadrons in Submarine Group Two, the Naval Submarine School, the Naval Submarine Support Facility, the Naval Undersea Medical Institute, and many more submarine support activities. One mile down the Thames River is the Electric Boat Division of General Dynamics, builder of all classes of U.S. nuclear submarines. Several colleges and universities are nearby, including the U.S. Coast Guard Academy, Connecticut College, and the University of Connecticut. NSMRL's three multi-disciplinary research departments use highly capable facilities including three hyperbaric

chambers, anechoic chambers, auditory and vision laboratories, closed atmosphere test room, diving boat, technical library, and Naval Underwater System Center, NUWC's Dodge Pond Open Water Diving and Sonar Test facility.

(2) Capabilities:

- 3 Hyperbaric Chambers (1 Saturation)
- 1000m^3 Anechoic Chamber
- 140m^3 Reverberant Chamber
- 10 Audio Testing Booths
- Vision Research Suites
- Closed Atmosphere Test Room
- Diving Work Boat
- Technical Library

(3) Floor Space:

- Building 148 6,480 sq ft
- Building 141 19,930 sq ft
- Building 156 17,952 sq ft

d. Mission Accomplishments by FY04 Research Work Unit

Submarine Medicine & Survival Systems Department
CDR W. G. Horn, MC, USN, Dept. Head.

Work Unit #5403
Title: Study on Prediction of Submarine Service Disqualifications
Principal Investigator: M. N. Bing, Ph.D.

Accomplishments (FY04):

In FY04 the SUBSCREEN answer sheets were improved to reduce test-taker errors, and a new scanner was programmed for the scoring of the new answer sheets. This accomplishment will increase the accuracy of the SUBSCREEN test results, and thus the accuracy of SUBSCREEN referrals of BESS students for subsequent mental health status interviews used to determine whether or not they are "psychologically fit" for submarine training and duty.

The SUBSCREEN program performed a tasker for COMSUBPAC to determine whether or not the SUBSCREEN test and SUBSCREEN's SubMarine Attrition Risk Test, SMART can predict suicidal events (i.e., suicidal ideation, gesture, and suicide attempt) in the Pacific Fleet (SUBPAC). The results were exceptionally positive; SUBSCREEN and SUBSCREEN's SMART predict suicide events in the Pacific Fleet, and SUBSCREEN refers a large portion of those BESS students who eventually engage in suicidal attempt to the Mental Health Clinic for mental health status interviews while still in the training pipeline.

A white paper was generated (which is being transitioned into a Technical Report) which presents the analysis of the SUBSCREEN Profile for an ET3 that has been charged with a double-homicide.

In FY04 BUMED 6.4 funds were secured (FY04-to-FY06) to test and evaluate the application of the SMART to interventions during submarine training that are intended to reduce misconduct and attrition, and increase performance, among BESS students.

Work Unit #5708
Title: Submarine Atmosphere Health Assessment Program
Principal Investigator: SurgCDR P. Benton, Royal Navy, S. DiNardi, Ph.D., and R. Woolrich

Accomplishments (FY04):

During the first half of FY04 SAHAP has continued to perform air sampling onboard submarines deploying for in excess of 28 days. Not all submarines are visited by SAHAP personnel due to limited funding, however, a representative sample of East and West Coast submarines both SSN and SSBN are sampled. To date during FY04 a total of 10 submarines

were visited and atmosphere sampling achieved. It is anticipated that a total of 20 submarines will have been visited before the end of FY04.

Work Unit #5903
Title: Prediction and Prevention of Submarine Service Disqualifications
Principal Investigator: M. N. Bing, Ph.D.

Accomplishments (FY04):

Findings from the Retrospective Study (Phase I) indicate that SUBSCREEN is a significant predictor of disqualification from the submarine force. Statistical analyses revealed that a discriminant function based on optimally predictive SUBSCREEN subscale scores successfully categorized 60.1% of those screened into one of two groups, successful vs. unsuccessful submariners, using a cross-validated grouping procedure (i.e., jackknife procedure). The SUBSCREEN profile reports were modified such that the probability of negative separation, provided by the discriminant function, is now printed on the report. This function has been labeled the SubMarine Attrition Risk Test (SMART). The probability of disqualification provided by the SMART is now used as a decision aid by the mental health status interviewers to reach a final disposition on BESS students who are referred to the Mental Health Clinic on the basis of SUBSCREEN referral criteria. Therefore, the research of Phase I has been transitioned into a product (i.e., a decision aid), the SMART, that is now currently being used by the Navy to identify submariner trainees that are at risk for early and negative attrition, and that may be unsuitable for submarine service. Also, BUMED 6.4 funds were secured (FY04-to-FY06) to test and evaluate the application of the SMART to interventions during submarine training that are intended to reduce misconduct and attrition, and increase performance, among BESS students. Data collection for Phase II, the Prospective Study, is still ongoing.

In FY04 SUBPAC waiver and disqualification data were obtained for CY01, CY02, and CY03. These data have now been cleaned and entered. SUBLANT waiver and disqualification data have also been obtained, and will soon be cleaned and entered. These data sets will then be combined and subsequently merged with the database containing Millon and SUBSCREEN test scores for those 1121 BESS students who volunteered for the study protocol in FY99, FY00, and FY01.

Work Unit #50202
Title: Feasibility of Using Hand-Held Personal Digital Assistants (PDAs) in a Hyperbaric Environment and the PDA-based Submarine Escape and Rescue Calculator and Information Library (SERCIL)
Principal Investigator: CDR W. G. Horn

Accomplishments (FY04):

- Chamber testing completed
- Palm Vx model PDA was successfully operated at pressures up to 132 feet of sea water, with a chamber diver able to perform calculations at that pressure.

- Further chamber testing demonstrated the ability for other models including the Sony Clio, Palm VIII, Casio, Hewlett Packard Jornado and Palm III to perform under pressure.
- Software development was initiated and 90% completed, incorporating guidance and formulae in the submarine class Senior Survivor Guides (Guard Books) into the program.
- Developed emulator version for SSBN 726 class
- Demonstrated to the Deep Submergence Biomedical Review Group and the CNO N77 Submarine Escape and Rescue Working Group.

Work Unit #50210
Title: Submariner Bone Turnover and Vitamin D Supplementation
Principal Investigator: D. Watenpaugh, Ph.D.

Accomplishments (FY04):

The results of the study: 1) confirm earlier studies demonstrating that lack of sunlight during submarine deployment causes vitamin D deficiency; 2) demonstrate that 400 IU / day vitamin D supplementation fails to correct this deficiency; and 3) suggest that the deficiency affects some aspects of calcium and bone metabolism, with unknown long-term consequences. This study and prior literature clearly indicate a need for vitamin D supplementation during submarine deployment. After considering safety, efficacy, and operational practicality, we recommend 50,000 IU vitamin D per month of deployment, distributed by the IDC in oral form to all crewmembers.

If deployments lengthen or women begin serving aboard submarines, questions addressed by this report may require reinvestigation. Also, while chronic vitamin D deficiency has been studied extensively and is well understood, the effects of repeated intermittent transient decreases in vitamin D levels, such as occur in submariners, are less studied. Sailors have experienced prolonged submergence and sunlight deprivation on nuclear submarines for nearly 50 years and, to date, there is no anecdotal evidence that career submariners have a higher incidence of fractures or other skeletal problems than their non-submariner peers. However, this possibility remains unexamined scientifically, so epidemiologic study of submariner bone density, fracture incidence, and arthritis morbidity vs. matched controls offers one future research opportunity.

Journal article and Technical report in progress.

Work Unit #50301
Title: Testing & Evaluation of a Low Cost Retractable Needle Safety Syringe for Naval Health Care
Principal Investigator: D. Watenpaugh, Ph.D.

Accomplishments (FY04):

NSMRL submitted, presented, revised, and earned approval of IRB protocols for laboratory and clinical safety syringe evaluations (approved: 6 Oct. 03). The PI successfully underwent physical certification and diving pressure test in support of his participation as a subject in the altered pressure components of syringe testing. NSMRL enlisted the collaboration and support of clinical evaluation partners at the Naval Ambulatory Care Clinic, Groton, CT. We completed design, assembly, and procedures for all systems necessary to expose syringes to heat and cold.

We established temperature and pressure limits for operationally relevant environmental simulation for syringe testing. The safety syringe project contributed importantly towards certification of the NSMRL Genesis chamber hypobaric capability. This ongoing work includes hardware design and modification, hypobaric operations training, and bureaucratic approval processes.

The original proposal called for cursory evaluation of a currently available competitive product to the SMI safety syringe as insurance against failure of the SMI syringe. The Vanishpoint syringe by RTI, Inc. is commercially available and currently in use in Navy clinics. NSMRL tests of this product in most of the targeted extreme environments suggest it operates reliably well in those environments. However, we did not test enough RTI syringes to draw this conclusion with full confidence, because the project was not funded to perform comprehensive evaluation of non-SMI syringes. We understand from our clinical partners that the RTI product performs well in the Navy clinical setting. However, it is relatively expensive.

NSMRL assessed FY03 SMI contract performance as unsatisfactory. SMI changed manufacturing sub-contractors due to inability of the former sub-contractor to overcome technical hurdles, deliver on time, and promise future high-volume production. Manufacturing design work is now moving forward, albeit slowly, towards syringe production with the new sub-contractor, the Tech Group, Scottsdale, AZ. SMI now submits monthly progress reports detailing status and steps towards specific and agreed-upon milestones. The first of these reports indicates adequate recent progress to date (22 June 04), but safety syringe manufacturing remains in a “probationary” mode.

Work Unit #50303
Title: Pulmonary Function
Principal Investigator: Surgeon Commander P. Benton, Royal Navy

Accomplishments (FY04):

Data collection continued throughout FY04 with the aim to obtain data from 5000 subjects. It is estimated that approximately 3500 subjects will be screened within this FY with the remainder screened during the first half of FY05. By collecting data from a total of 5000 subjects it is predicted that approximately 500 sets of data from the smallest ethnic group (Hispanic) will be collected. This is a comparable number to the sample size analyzed by Hankinson to produce lung function reference values.

- Nov03: Logistics re data collection resolved, data collection commenced.
- Dec03: Data collection ceased during 2 week shutdown of SubSchool.
- Jan04: Data collection recommenced.
- Apr04: Approximately 800 subjects screened.
- May04: Progress report delivered at NAVSEA/ONR meeting in Baltimore.

Work Unit #50304
Title: At-Sea Trials of NSMRL Watchstanding Regimen
Principal Investigator: LT C. Duplessis, LCDR L. Crepeau

Accomplishments (FY04):

NSMRL researchers and crew set out on the SSBN cruise following the 6/12 schedule for 3 days, then shifted to the alternative schedule. However, that schedule was first initiated at midnight, vice noon, as designed. The crew followed that schedule for 13 days, then shifted so the alternative schedule would begin at noon; this was followed for 6 days. After that, the 6/12 schedule was re-adopted for the remainder of the cruise, i.e., 11 days.

The Henry M. Jackson crewmembers provided feedback on the compressed work schedule. The negative sentiments of the crew reflected how the schedule did not provide the time needed to accomplish ancillary tasks (e.g., training, qualifications, drills, and rest) between watches. When the subjects reached their 24-hour break on the 3rd day, they routinely spent at least 12 hours sleeping.

A videoteleconference (VTC) was held at Naval Submarine School, Bangor, WA, on 4-5 Mar 2004. This VTC provided the researchers with frank and open communication with the crew of the Henry M. Jackson, along with representatives from Norfolk and Pearl Harbor. Various alternative schedules were discussed:

1. a fixed, 8-hour,
2. a compensated 6-hour dogged,
3. and a fixed, 6-hour dogged.

After evaluating each candidate schedule based on the Fatigue Avoidance Scheduling Tool (FAST), the group agreed that the fixed 8 shift appeared to provide the greatest promise of simultaneously entraining submariners on a biologically-sensible 24 hour "day," provide sufficient time off each 24 hour period to accommodate sleep, and allow entrainment of the appropriate circadian rhythm for watchstanders on the swing and midnight shifts, enhancing their performance levels.

NSMRL secured a no-funds extension for BUMED appropriation 03-1319, providing us the funds needed to conduct the laboratory-based evaluation, and we are currently writing a budget to secure the necessary equipment, personnel, and cover overhead charges.

Work Unit #50307
Title: DISSUB – US Navy Simulated
Principal Investigator: CDR W. G. Horn

Accomplishments (FY04):

A paper: "A Trial Of Survival Capabilities Aboard A Simulated Disabled U.S. Navy Submarine" was presented at the Submarine Atmosphere Monitoring and Atmosphere Purification Conference (SAMAP) Oct 03

Surgeon CDR Benton attended the UK Royal Navy ESCAPEX 2003 in Scotland 17-18 November. Thirty-six personnel completed escapes from HMS VIGILANT, an 18,000 ton SSBN, which was moored between buoys in Loch Goil at an escape tower depth of 100 ft. The exercise demonstrated that the combination of the Mk10 Submarine Escape Immersion Equipment (SEIE) and the 2 man Logistics Escape Tower (LET) fitted to UK SSBNs, and the aft compartment of ASTUTE class SSNs, currently in build permits safe and effective escape from a disabled submarine. None of the escapees suffered any injury and there were no cases of decompression illness or ear barotraumas. Three of the escapees were volunteers from the submarine crew, and the remainder were submarine escape-training instructors. The Mk10 SEIE is identical to that what U.S. Navy submarines are being equipped with.

Work Unit #50402
Title: Submarine Attrition Risk Test (SMART)
Principal Investigator: Mark Bing, Ph.D.

Accomplishments (FY04):

In the first quarter of FY04 the computer program which scores the SUBSCREEN test results was modified and improved to calculate and print out the SMART (formerly SARS) results for each BESS student.

A prototype of the computer program that will be used to acquire behavioral and academic outcomes (i.e., the dependent variables in the research design) from NAVSUBSCOL leaders on BESS students in the submarine training pipeline was also designed and created. This computer program will allow both NAVSUBSCOL and NSMRL to track submariner careers more easily and accurately, and it will also be used to gather the dependent variables by which the effectiveness of the release of the SMART to NAVSUBSCOL is to be evaluated.

In the second quarter of FY04 the first draft of the Institutional Review Board (IRB) research protocol was written, distributed to the co-chairs of the IRB and to co-investigators, and conditionally approved by NSMRL's IRB on 24 March 2004 (IRB protocol #NSMRL2004.0005). Revisions were required and made by the PI. These revisions concerned the intervention at NAVSUBSCOL, and the CMC of NAVSUBSCOL concurred with these revisions on 27 April 2004. The IRB protocol was subsequently revised on 27 April 2004, and then resubmitted for final approval on 27 April 2004. The IRB protocol was approved on 03 May 2004.

The overall list of activities for the intervention was created, and the amount of time for the intervention was estimated. These aspects of the intervention were forwarded by the PI to the primary NAVSUBSCOL member of the IPT (i.e., CMC Crisman), and the PI received the

CMC's concurrence for these aspects of the research protocol on 27 April 2004. The overall list of activities and the estimated amount of time were subsequently used to revise the IRB protocol on 27 April 2004. The revised IRB protocol was then resubmitted for final IRB approval on 27 April 2004. The IRB protocol was approved on 03 May 2004.

This project was used to generate a submariner tracking program that will be used to merge various databases at NAVSUBSCOL that are currently separate (e.g., instructor evaluation ratings, student grades, NJP records, etc.) into an omnibus, master database. This paperless system will increase the efficiency and effectiveness of tracking submariner careers, and will also allow the Navy to determine the critical training events that serve as career enhancers and predictors of submariner success.

Work Unit # 50403
Title: Heat Stress
Principal Investigator: CDR W.G. Horn, MC, USNR

NSMRL hosted the Disabled Submarine Heat Stress Conference on 22 June 2004 at Groton. The conference, funded by the Deep Submergence Biomedical Research program at COMNAVSEASYSCOM, convened to address the problem of potential heat stress in submarine disaster scenarios. Items discussed included the impact of heat on escape-versus-await-rescue decisions, heat mitigation efforts, heat stress condition measurement and water requirements. CDR Wayne G. Horn chaired the workshop, which included panel members from the U.S. Army Research Institute for Environmental Medicine, Naval Health Research Center, Naval Environmental Health Center, and the Submarine INSURV Board.

The primary deliverable is a report of the conference findings, with specific recommendations for Evaluation and Management of Heat Stress in the DISSUB.

This report will include:

- Submarine systems, performance parameters, authorized equipage, and current procedures applicable to the problem of DISSUB heat stress in high ambient temperatures.
- A consensus regarding the suitability of heat stress monitors, WBGT instruments, and other Authorized Equipage List items on board for use in DISSUB scenarios, with recommendations for other equipment if not currently carried aboard submarines.
- Recommendations for alternative heat stress measurement techniques in lieu of WBGT instrument measurements.
- Guidance and recommendations for mitigation of heat stress.
- Recommendations for use or modification of PHELs for use in DISSUB scenarios and recommendations for charts and tables.
- Recommendations for specific temperatures and conditions that should result in initiation of escape and temperatures and conditions by which time escape should be completed.
- Heat casualty treatment guidance in the DISSUB environment.

Work Unit # 50406
Title: Distinguishing Clinical Depression from Malingering
Principal Investigator: Mark Bing, Ph.D.

Accomplishments (FY04):

The FY04 funding for this project was received on 16 December 2003.

An extensive literature review was conducted, and psychological instruments required for this feasibility study were identified, such as the Attribution Style Questionnaire (ASQ), the Conditional Reasoning Test (CRT), the Positive and Negative Affectivity Scale (PANAS), and the Beck Depression Inventory (BDI).

Contact was established with Dr. Seligman for use of his ASQ at a discounted rate in this not-for-profit research. Contact with IAT was established for use of IAT's CRT, and an agreement with Psychological Corporation for use of the BDI was obtained. All relevant psychological instruments were subsequently purchased and/or the rights to use those tests were secured.

The research proposal was revised to explain the integration of the current study with NSMRL's ongoing psychological screening operation, known as SUBSCREEN (see Work Unit #5403).

Additional FY04 funding was received on 06 February 2004. The research proposal was revised to outline the expenditure of the additional funding.

Contracts with academic researchers were completed to facilitate the accomplishment of this research, and the Principal Investigator worked with the academic collaborators to generate the test battery for the first phase of data collection.

The omnibus test battery was completed and the two instructional sets were created for Phase II.a. of the research, instructions for those in the malingering simulation condition versus those in the general research condition.

A total of 278 students completed the test battery after being randomly assigned to one of two study conditions (malingering simulation condition versus general research condition). Other students have volunteered to complete the test battery since this first administration session, and the current total number is 289 research participants.

The IRB protocol was revised to allow students to volunteer to take the test battery a second time under the alternative instructional condition (i.e., malingering simulation condition versus general research condition) that they did not receive the first time. This changed the research design from a purely between subjects research design to a repeated measures research design. Approximately 164 of the original 289 students volunteered to retake the test battery under the alternative instructional condition that they had not previously received. There are multiple benefits that result from this change: test-retest reliability coefficients across instructional conditions can be calculated, an assessment of the extent to which

participants can change their scores when motivated to do so can also be made and calculated, etc.

Work Unit # 50407
Title: SEE/RESCUE Distress Streamer
Principal Investigator: CDR W.G. Horn, MC, USNR

Accomplishments (FY04):

Task 1: Validate Target Configurations

Goal: Verify and document conditions under which PIW and SEIE search objects equipped with See –Rescue streamer device (S-R) can be anchored within a test area without substantially altering their appearance.

Task 2: Detection Performance Testing

Goals: (1) Statistical comparison of the detectability of two search objects; a PIW w/submariner's PFD/survival suit and an SEIE raft, when equipped with vs. without a S-R. (2) Determine the LRC function and sweep width for both search objects. Two sensor types shall be evaluated; (1) the unaided eyes of P-3 and H-60 aircrews during daylight and (2) NVG-equipped P-3 and H-60 aircrews using NIR illumination at night.

Task 3: Develop and Validate TAWS Models for PIW and SEIE w/ S-R

Goal: Develop AFRL-approved and RDC-validated TAWS target models for PIW and SEIE search objects equipped with See –Rescue streamer device (S-R) to support detection range predictions for a wider variety of conditions and sensors.

Task 4: Leeway Drift Testing

Goals: (1) Collect field data on the leeway drift characteristics of the SEIE raft, when equipped with vs. without a S-R over a range of wind speeds. (2) Statistically determine the downwind and crosswind components of leeway of the SEIE rafts as functions of the 10-meter winds. (3) Report on any secondary leeway drift characteristics observed for the SEIE rafts. (4) Check the forcing terms of Hodgins and Hodgins' (1998) leeway model with the collection of directional wave data and surface current fields, and (5) collect field data on the leeway characteristics of the Submarine Emergency Position Indicating Radio Beacon (SEPIRB).

Diving & Environmental Simulation Department
E. A. Cudahy, Ph.D., Department Head

Work Unit #50204
Title: Guidance and Protection for Exposure to Ultrasound
Principal Investigator: E. A. Cudahy, Ph.D.

Accomplishments (FY04):

During year one, the acoustic setup and calibration for ultrasonic signals (>20kHz) was completed, and during year two, human testing to determine the highest audible frequency for humans in-water was obtained.

- IRB Protocol approval
- Measurement of open ocean sound attenuation for wet suit hood
- Measurement of high frequency thresholds to 190 kHz
- Fleet guidance provided for several new sonar systems
- Sonar test and evaluation programs have all been accomplished

Work Unit #50205
Title: Underwater Impulse Noise Protection
Principal Investigator: E. A. Cudahy, Ph.D.

Accomplishments (FY04):

Phase 1 has been completed. The purpose of Phase 1 was to generate impulse signals with different time waveforms, in order to sample the key parameters within the range identified as causing different effects in air. The PI developed approximately 10-12 waveforms that capture the range of key parametric manipulations.

The major focus for the current year was to collect data on the sound protection provided by current wet suit hoods against impulse noise as a function of the rise/fall time of the noise. This experiment was conducted and data analysis has begun. Preliminary findings are that the shorter rise/fall time signals are attenuated more than the long rise/fall time signals. However, none of the signals was attenuated more than an average of 7 dB.

Energy, time waveform, and spectral analyses were completed for the waveforms used in the threshold/loudness experiment conducted last year and the sound protection experiment this year. The outcome data from the two experiments will be analyzed using each of these three descriptive approaches for derivation of functions describing the perceptual behavior for threshold, loudness, and sound protection. These derivations will determine which of the three approaches provides the best way to describe behavior. The goal of the analysis is to provide modeling rules for underwater impulse noise assessment.

A technical report has been initiated.

Work Unit #50206

Title: Effects of Carbon Dioxide and Oxygen Levels on Auditory Sensitivity and Frequency Tuning Curves

Principal Investigator: CDR K. S. Wolgemuth

Accomplishments (FY04):

- A reliable non-commercial, SFOAE system to validly measure otoacoustic emission amplitude and phase rotation was developed.
- 3400 data points were collected on 10 subjects under control and experimental gas conditions.
- The majority of the data has been analyzed.
- A Navy Technical Report has been started (Introduction, Background, and Methods sections are complete).

During 3-13 November, CDR Keith Wolgemuth, MSC, USN, PI and Command Diving Officer at NSMRL, conducted in-water noise measurements of the Aquanaut in-water diver recall system at the National Oceanic Service Aquarius Undersea Habitat in Key Largo, FL. In addition, he performed topside noise measurements on the dive station and within the generator and compressor spaces of the Life Support Buoy for the habitat. These data were collected as part of a BUMED 6.4 study that examined in-water and in-air noise exposures for Navy divers, as they are used routinely as volunteer divers supporting the scientific missions of the habitat. CDR Wolgemuth also worked with University of North Carolina, Wilmington divers providing technical diving support for an Aquanaut mission that was studying the survival defense mechanisms of different algae species living on a large coral reef.

Work Unit #50207

Title: Mechanisms to Improve Nitrogen Elimination and Reduce the Incidence of Altitude Decompression Sickness

Principal Investigator: D. Fothergill, Ph.D.

Accomplishments (FY04):

Developed, built and tested a neck pressure device for experiment 1B.

Conducted repeated LBPP measurements on 9 subjects to assess the repeatability of the impedance techniques for measuring relative changes in cardiac output, and limb blood flow during LBPP.

Conducted and completed second phase of experiment one: Cardiovascular responses to constant graded LBPP while applying positive neck pressure.

PI invited to represent the US Navy at the Joint Indo-US Workshop on "Enhancing Human Performance in Military Environment" 11-13 November 2003, New Delhi, India. An aural

presentation was given on "enhancing performance in the undersea environment". This paper highlighted diving within the US Navy both present and future.

Presented findings of Experiment 1 on Cardiac output and limb blood flow responses to graded leg positive pressure (LPP) while seated at the 75th Aviation Space Environmental Medicine Annual Scientific Meeting, Anchorage, Alaska, May 2-6 2004. Results from this experiment define the optimum leg positive pressures for increasing blood flow to the legs in a sitting resting individual.

Presented progress and provisional findings at the Annual NAVSEA Deep Submergence Biomedical Development/ONR Undersea Medicine Progress Review held in Baltimore, MD, May 10th -12th, 2004.

Presented progress and provisional findings by VTC on June 8th, 2004 for the Core Capability 2004 Program Review, Naval Health Research Center, San Diego, CA.

Completed Experiment 2 comparing intermittent LBPP and constant LBPP on cardiac output and limb blood flow responses.

Work Unit #50212
Title: Underwater Sound Localization
Principal Investigator: E. A. Cudahy, Ph.D.

Accomplishments (FY04):

The goal of this work unit is to determine the accuracy of underwater sound localization by naïve and experienced divers as a function of frequency and intensity. Divers frequently report uncertainty about the direction of sound under water. Limited data suggests the divers can localize underwater sound, but the data is sparse and covers only frequencies below 8000 Hz. At these frequencies, the wavelength is much longer than the width of the head so normal sound localization cues are not present. In addition, bone conduction is the primary transduction modality for the auditory perception of underwater sound. There is some suggestion that divers can improve with practice even under these conditions.

The first phase of testing at 100 - 4000 Hz was completed in FY03.

01OCT03-30SEP04 - Second phase of testing, expanding to 16000 Hz was completed. Divers gave almost constant performance across frequency with all divers able to consistently localize underwater sound at angles of 30 degrees or greater. The final phase incorporating training and rapid onset/offset to determine the optimum set of parameters for underwater localization is scheduled for Sep 04.

Major Accomplishments

Completed testing at 100 - 16000 Hz

- First measurement of the ability of divers to localize underwater sound at frequencies below 500 and above 8000 Hz.
- First measurement of the impact of wet suit hoods on underwater localization.
- Given multiple trials for two speakers divers were consistently able to localize sound at an angle of 10 degrees at 200 Hz.
- Divers were able to localize sound at other frequencies within the test range, but the minimum audible angles were greater.
- Divers can localize underwater sound and that performance will improve even through informal training.
- Hoods did not significantly affect localization ability.

The Diving and Environmental Simulation Department executed a diving experiment at the TRANSDEC facility in San Diego 12-22 November 2003. This experiment is part of a series of experiments measuring underwater localization ability for naïve human divers. It has been established that humans do not localize sound as well in water as they do in air. The frequency range from 100 – 4000 Hz was tested along with preliminary data collected at higher frequencies. Divers from the Deep Submergence Unit in San Diego served as subjects along with the dive team from NSMRL. The measurement of minimum audible angle is critical to determine the fundamental ability of a diver to localize a sound underwater. This data will serve as the basis for the next experiment in the series investigating the impact of training on underwater localization performance.

Work Unit #50308
Title: Non-Lethal Bioeffects of Underwater Sound
Principal Investigator: E. A. Cudahy, Ph.D.

Accomplishments (FY04):

This project began in March of 2003. The first part of the year focused on setup. The projector and test site selections have been confirmed. The human use protocol has been approved by the Institutional Review Board and data collection is underway.

The data being collected represent the first quantitative measurement of vibration sensation in divers for underwater sounds from 20 - 100 Hz. Preliminary data suggests that duration is an important parameter for vibration sensation with a significant decrease in vibration threshold as duration is increased.

In addition to the duration parameter, the effects of a wet suit on vibration threshold are being investigated. This study will also collect further data on the lung resonant frequencies of divers as a function of depth. This is critical for determining the variability of diver lung resonant frequencies. This variability and the effects of frequency on vibration threshold will allow assessment of the opportunity to provide non-lethal deterrence using underwater low frequency sound. If the variability among divers is large and the vibration sensation narrowly focused around the resonant frequency, then it will be difficult to design a non-lethal deterrent using this approach. A narrow range of resonant frequency will offer a much higher probability of success. Success may also be possible if the vibration sensation is broadly

focused such that variability in lung resonant frequency does not restrict the impact of the low frequency sound. The current data collection will provide these answers.

Work Unit #50409
Title: Conduct Diver Test of Water Gun and Noise
Principal Investigator: E. A. Cudahy, Ph.D.

Accomplishments (FY04):

The Diving and Environmental Simulation Department just completed a five-week dive series involving potential impulse noise systems for use in anti-swimmer force protection. Five systems using different approaches to generate impulsive underwater sound were tested. The systems were evaluated for their reliability and sound generation capabilities as well as their effectiveness in deterring swimmers/divers. This project was a joint effort between NSMRL, John Hopkins University, Naval Facilities Engineering Science Center, the Coast Guard Research and Development Center, Coastal Systems Station, and the Joint Non-Lethal Weapons Directorate.

Work Unit #50410
Title: Develop Ear Seal for Head-Mounted Hearing Protection
Principal Investigator: E. A. Cudahy, Ph.D.

Accomplishments (FY04):

- CRADA arrangements finalized.
- Equipment allocation and distribution finalized.
- 6-week plan developed for material production and testing.

This project will have two primary phases. The first is the development of the ear seal with improved passive attenuation properties and the second is to insure that multiple ear seals with these properties can be produced in a timely and reproducible manner.
Our general approach for development of the seal will be similar to that which has proven to be successful in the Navy's past efforts to apply the proprietary technology to such materials as silicon- and carbon-based rubbers and gels, epoxy resins, polyurethanes, etc. We will evaluate and select candidate materials and enlist the cooperation of suppliers and CRADA partners to provide optimized candidate materials. We will test the materials in the laboratory to confirm sound attenuation properties. The criterion for a suitable seal will be a seal that provides more attenuation than any current seal.

For phase 2, after choice of the most suitable seal, we will have the CRADA partner (Elastocal) produce 10 ear seals in a batch. This will assess production issues. Assuming that 10 seals can be produced quickly, they will be tested to see if they meet specifications based on the candidate formula that produced the most successful seal in phase 1. If the seals pass the testing, they will be the basis for the materials to be transferred to our collaborator.

Human Performance Department
CDR K. S. Wolgemuth, MSC, USN, Department Head

Work Unit #50106
Title: Audio Technology & Management in Modern Navy Systems
Principal Investigator: T. P. Santoro, Ph.D.

Accomplishments (FY04):

Experiments were designed and carried out in FY03 to determine effects of a spatialized audio presentation mode on passive sonar listening. Results supported the use of up to seven simultaneous audio channels for the purpose of recognition of well-known sonar transients in the presence of typical continuous and transient distracter sounds. This completes the work plan for this study. A new start proposal has been submitted to ONR Code 342.

Major Accomplishments

- Designed and ran experiments using Method of Recognition Memory
- Determined number of useful simultaneous audio channels for average sonar listener is seven
- Work unit completion. Follow-on proposal has been made.

Work Unit #50211
Title: Advanced Binaural Displays for Collision Avoidance in Close-In Undersea Environments
Principal Investigator: J. S. Russotti, M.S.

Accomplishments (FY04):

SVBF processing has been developed and successfully applied for unique binaural presentation of audio sonar data. For SVBF within a single directional beam, time delays are a function of direction and distance. Maximum received signal occurs when source is "in focus." Focal distance is kept different at each ear. While the beam-forming method differed from our initial adjacent formed beam-pair concept, the end result at the ear was identical to our requirements and had far better noise cross-correlation. Since any target present will have greatest energy when a beam is focused in distance at its actual location, a target intensity difference is created relative to shorter or greater distances. As the system presents each ear with beams formed at the same bearing focused to different distances, the processing creates a spatial vernier across the two ears.

Phase I research showed that noise cross-correlation could be theoretically maintained at a very high degree while target intensity would be greatest at the distance of the target [1].

Having now developed novel methods to optimize the cross-correlation of sea-noise in a single pair of highly-focused formed beams, real world acoustic target signals were selected

for perceptual testing. In Phase II research these beam-forming algorithms were applied to a database of 15 representative acoustic sonar target signals. This portion of the work to digitally beam process the target signals was conducted over several months in collaboration with NAVSEA Naval Undersea Warfare Center. Since the binaural presentation format differed from our original concept, the threshold detection test procedures had to be significantly revised. Instead of a target search across bearings using a sonar simulator, an adaptive threshold tracking test procedure of known reliability was converted to present the test stimuli to aurally trained sonar operators. The test procedure required Windows based software development, converting algorithms originally based in MS DOS with significant data-logging refinements added. All target signals (normal and experimental) were "beamform" processed and loaded into digital storage. Binaural sound file-pairs, processed through the beamform algorithm at different detection levels, were stored in a matrix and selected for presentation according to an adaptive threshold tracking procedure. Data collection algorithms were successfully pilot tested using the appropriate target wave files. Subsequently, subject testing and data analysis were completed. The test population consisted of 17 highly experienced aurally-trained submarine sonar operators currently attending advanced training to become sonar supervisors. Results show a highly significant 6.8 dB average detection improvement over the current single-beam display. This is a highly favorable improvement that represents the ability to detect targets at more than twice the distance currently achieved.

The SVBF processing is currently also under consideration for application in unmanned undersea vehicle (UUV). The SVBF dual beam data is ideal for adaptive real-time signal processing, since the noise common to the two beams can be mathematically removed to expose the target. As a result SVBF processes are amenable to real-time digital signal extraction for 3-D audio displays which are ideal for situational awareness.

Based upon our positive preliminary findings using the simpler linear sonar array, SVBF processing is currently undergoing theoretical application to the Wide Aperture Array (WAA) which has far better audio bandwidth and bearing resolution. The broader bandwidth more perceptually useful WAA will provide a more complex challenge to applying this spatial-vernier beam-forming technique to a more complex beam-formed array.

Work Unit #50214
Title: Human Performance Modeling of the MMWS Build 2 Workstation
Principal Investigator: T. P. Santoro, Ph.D.

Accomplishments (FY04):

Work with the Air defense Warfare GOMS team model continued in collaboration with Dr. Joe Divita of SPAWAR. A new analysis based on Queuing Theory was applied to compare model predictions and actual human team results. New work was started to model the Land Attack Warfare mission using the Tomahawk cruise missile controlled through a multi-modal watchstation interface.

Three different GOMS model teams were built to represent three distinctly different workload and communications styles observed in human Air Defense Warfare teams. Predictions of the team models were shown to provide reasonable latency and task duration time estimates to actual team performance when analyzed with the Queuing Theory technique.

Several iterations of the Land Attack Warfare HCI have been simulated in keeping with the development of the LAW Rapid Prototype (RPT) Simulation built by SPAWAR. The latest GOMS model reflects the RPT of August, 2003 and will be presented as part of the SPAWAR development program demonstration in the November, 2003 year-end review. It predicts performance of a single operator managing multiple electronic strike packages in a scenario with realistic time requirements and fault events. The scenario will be tested on individual LAW operators using the RPT watchstation and their task execution latencies and workload will be compared to the GOMS model prediction.

Funding for further work on the SPAWAR program is uncertain at this time. However, plans do exist for extension of the individual model to a 4-man team and prediction aspects of communications and workload sharing during typical LAW scenarios.

Work Unit #50305
Title: Working Memory Components of Situation Awareness
Principal Investigator: LT K. Shobe

Accomplishments (FY04):

Phase 2, data collection, was completed in FY04. Data were collected from 10 novice submariners, and 8 expert submariners. Due to difficulty in obtaining subjects, data collection will continue in FY05.

Phase 3, data analysis, was also completed in FY04. Results are as follows:

WM Capacity:
To determine validity of each measure in order to select the best WM measurement, a correlation matrix was done for these 6 WM capacity measures; domain-specific verbal, domain specific spatial, domain specific spatial & verbal, domain-general verbal, domain general spatial, domain general spatial & verbal. It is purported that if the domain general capacity correlates moderately with the domain specific capacity measuring the same skill, the two measures will show convergent validity and therefore the domain specific capacity may be selected as the WM measurement. Both the spatial and verbal & spatial WM capacities were correlated. Because the focus is to measure both spatial and verbal, the verbal&spatial domain specific capacity was used for all analyses. Additionally, WM capacity was not dependent on expertise level, as confirmed by nonsignificant t-tests.

LTWM Skill:
Experts showed better mean recall accuracy for meaningful, nonmeaningful, and LTWM skill than the novices. T-tests showed the meaningful memory skill tasks to differ significantly

between the 2 groups, [t(15) = -2.19, p =0.05)]. This was not the case for the nonmeaningful [t(15)= -1.64, p = 0.12] and the LTWM [t(15) = -1.29, p=0.22] tasks.

SA Performance:
The four situational awareness measures (SA), overall, single, double dependent and double independent dprimes, did not differ between the novice and expert group. Additionally, no situational awareness measure correlated with LTWM for either group.

Regressions:
Based on the above results, the following regressions used the verbal&spatial domain specific WM (WM) and LTWM measures as predictors (independent variables) alone and in combination, and the overall situation awareness score (dprime, dependent variable) as the criterion.

Hierarchical Regression:
This analysis included the predictive measures of WM capacity, LTWM skill measure and the cross product of the WM capacity by LTWM skill measure. Predictors were entered into the model in that order. The results of the hierarchical regression that included both groups were not significant ($p>0.05$) for either main effect or for the WMxLTWM interaction. That is, neither WM capacity, LTWM, nor their interaction accounted for a significant amount or increase of the variance in the situation awareness measure.

When regressions were done separately for each group, significant increases in variance were found. For the novices, WM accounted for 46% of the variance found in the situation awareness measure ($p=.04$). For the experts it was the interaction of WM and LTWM that accounted for 65% of the variance found in the situation awareness measure ($p<.01$). This suggests that WM capacity assists with situational awareness performance for novices, and that the interaction of WM and LTWM assists with expert performance.

Using expert level in combination with z scores for WM and LTWM, two expertise scores were calculated (exp_wm and exp_ltwm) and used as additional predictors for situational awareness performance. A total of two regressions were done to determine if the regression lines differ as a function of WM or LTWM expertise when predicting SA performance. Expert scores = -1 for novices and 1 for experts.
The first regression included the following predictors; LTWM, Expert, and EXP_LTWM. Neither interaction of the predictors showed the regression lines to differ as a function of expertise. The same was true for the second regression that included the following predictors; WM, Expert, and EXP_WM.

Overall, given the small N to date, the above results are promising. Significant differences (and non-differences) were found in some areas as hypothesized. WM capacity was constant over expert groups, LTWM skill was better for experts, and these two measures played different roles in SA performance for the two groups. Other differences may emerge as the number of data points increases over the next FY.

Work Unit #50306
Title: Field Test – Noise Reducing Stethoscope
Principal Investigator: J. S. Russotti, M.S.

Accomplishments (FY04):

A contract was completed with the developer to field-ruggedize 6 prototype stethoscopes which were received for use in laboratory evaluations. These 6 devices are on loan until all testing is completed. Human testing protocols were approved by the IRB. As data collection began it was found that the devices allowed detection of visceral sounds at levels greater than anticipated from testing previous prototype models. As a result, the laboratory signal generating hardware needed to be significantly upgraded to produce the necessary sound pressure levels. The stimulus generating system underwent major redesign with upgraded sound drivers to accommodate those levels necessary for adaptive threshold testing. Once the redesign hardware was purchased and installed, the system was recalibrated to accurately recreate operational sound fields. Initial data collection revealed the necessity of upgrading the supplied stethoscope "ear-bud" earpieces on the test samples to improve noise-reduction. This was done successfully in-house using COTS items and will be retrofit on all future units by the manufacturer. At the request of the Marine Corps (via LCDR J.A. DaCorta), Expeditionary Medicine Marine Corps Warfighting Lab Quantico, VA, specifications were written at NSMRL and an additional contract has been let for the outright purchase 8 of the prototype stethoscopes for further field testing by the marine corps.

Externally, the NR stethoscope appears identical in form and function. Use-training is minor, it just works better in noisy operational environments than any conventional acoustic stethoscope because: 1) the thin-film pick-up sensor is immune to sound pressures that are present on both sides of the material 2) all of the signals picked up as the sensor head are converted to electrical signals that are only recreated inside the stethoscope ear-tip that is inserted in the ear much like an insert earphone.

Work Unit #50309
Title: EOAE - Army
Principal Investigator: L. Marshall, Ph.D.

Accomplishments (FY03):

A manuscript on NSMRL Longitudinal Otoacoustic Emissions Project was accepted for publication in the International Journal of Audiology. A manuscript on NSMRL TTS experiments ("A comparison of transient-evoked and distortion-product otoacoustic emissions following short-duration noise exposure in humans") was submitted to the International Journal of Audiology. A first draft of a large-scale study (>400 subjects enrolled) on Navy aircraft-carrier personnel was written, but further data analyses were needed and are being completed. Data analyses from another large-scale study (>300 subjects enrolled) on Marine recruits was essentially completed, and an abstract has been written for submission to the spring Acoustical Society of America meeting.

A prototype stimulus-frequency otoacoustic-emission (SFOAE) and transient-evoked otoacoustic-emission (TEOAE) measurement system (along with previously developed distortion-product otoacoustic emissions, or DPOAEs) was delivered by our subcontractor, Mimosa Acoustics, and tested by NSMRL. In so doing, Mimosa Acoustics resolved two major technical problems, one of which resulted in a major improvement for in-the-ear calibration of transient stimuli. A prototype system to measure contra lateral suppression most recently was delivered by Mimosa Acoustics.

NSMRL helped Mimosa Acoustics write a successful NIH-NIDCD SBIR grant to combine reflectance and DPOAE instrumentation. This development will be helpful for our hearing-conservation application, but the military will not have to pay for it as it also has application for infant hearing screening.

Validity and reliability data were collected using the new Mimosa Acoustics equipment. Data for the validity experiment were collected on 8 people (from 10 people screened) with severe to profound hearing-impairments (who should have no otoacoustic emissions – if they appear to have them, it is artifact). The otoacoustic-emission types were SFOAEs, and TEOAEs (both filtered clicks and chirps). Preliminary analyses showed that there was no artifact at the levels we want to use for testing, but there can be artifact at higher levels, particularly in the linear test mode. Data to determine how to equate the energy level of chirps vs. clicks and to determine how well a new stimulus-spectrum calibration works for clicks and chirps were collected on 14 ears (on 12 people). Preliminary analyses indicated that it was more appropriate to equate clicks and chirps in rms than peak SPL and that the spectral calibration developed by Mimosa Acoustics improved the reliability of the measurements. Data to determine test-retest reliability of SFOAEs and TEOAEs (both filtered clicks and chirps) were collected in 59 ears (from 33 people).

We developed a way to measure synchronized spontaneous otoacoustic emissions (SOAEs) on our new Mimosa Acoustics equipment. It is more sensitive (and just as fast) at detection of SOAEs than our older, commercially-available EOAE system. This is very important because it has become apparent that the location of these SOAEs needs to be known for the interpretation of SFOAEs as well as for other emission types.

In previous work, we demonstrated that EOAEs have great potential in hearing-conservation programs, but, as currently being implemented clinically (including both instrumentation and protocols), will not be successful in hearing-conservation programs (Lapsley Miller, Marshall, and Heller, 2003). Therefore, the current work was undertaken to develop the instrumentation, test paradigms, and test strategies that will be successful, and we have undertaken the first part of that work. New instrumentation has been designed with an emphasis on infant screening). Personalized, real-time calibration has greatly improved the reliability of measurements by removing the variation caused by differences in probe placement from test-to-test Synchronized SOAE measurements were developed by NSMRL for our new Mimosa Acoustics System. Eighty-one ears were tested in validity and reliability experiments.

The current research has implemented the most promising new techniques to stimulate otoacoustic emissions and has collected data on their validity and reliability. Data are being analyzed, and manuscripts are being written.

Work Unit #50405
Title: Understanding of Certain Sensory Behaviors
Principal Investigator: T. P. Santoro, Ph.D.
Accomplishments (FY04):

The PI has begun collaboration with Mr. Raymond Rowland, a principal investigator in the Acoustic Display Research Facility, Naval Undersea Weapons Center, Division Newport, (NUWC) on sonar applications for spatialized acoustic displays. Mr. Rowland is evaluating a commercial spatialized acoustic display device from the AuSIM Corporation for use with multi-beam passive sonar audio. His Head-Related Transfer Function (HRTF), along with others measured at NSMRL with the Wakefield-Cheng technique, is being adapted to the AuSIM device. Dr. Santoro is translating current NSMRL psychoacoustic experiments on target positioning and geometries in a synthetic auditory environment into the NUWC sonar auditory display interface using the AuSIM multi-channel HRTF-rendering engine with head-motion tracking. This will allow for the study of basic sensory-perceptual behaviors with this auditory interface in an operational sonar environment and lead to eventual evaluation of performance in operational exercises.

This project is testing the following two hypotheses:

1. The ability to detect, recognize, and localize objects of interest in a synthetic 3-D surround is dependent on the quality and quantity of the sensory information available, both acoustic and visual, and on the governing cognitive strategy used to collect and process that information for decision-making.

2. Learned cognitive strategies can be transferred from one sensory modality to another when analogous clues exist and are presented in an appropriate manner in the synthetic environment. The ability to reconstruct and maintain the perception of an environmental surround from a synthetic bi-modal sensory interface will be tested by experiments that determine the extent to which the observer can simultaneously attend to multiple objects in multiple directions or on multiple trajectories using the auditory modality both alone and together with the visual modality. Different parameters of both the auditory and visual interface such as head and source motion, backgrounds and landmarks, and reflections will be systematically introduced into the experiments and their effects measured. The learning of cognitive strategies and their cross-modality transfer will be tested in combinations of visual and auditory discrimination experiments with both unrelated images and sounds and with stimuli based on visual and auditory displays of sonar data.

Work Unit #50408
Title: Signal processing Requirements for Spatial-vernier (SV) audio-beamforming on Wide Aperature Array (WAA) for enhanced collision avoidance
Principal Investigator: J. S. Russotti, M.S.

Accomplishments (FY04):

The signal processing task carried out in this research over the past 12 months was to determine if differences between beams could be demonstrated using the onboard Wide Aperture Array (WAA) that were directly attributable to the target signal and if these differences can yield information as to where the target is located. Earlier analysis on a simpler linear hydrophone array shows that the characteristics of focused, or spatial vernier beamforming could be harnessed to produce the conditions needed to produce the effect. The first array that this technique was applied to was the current TB-29 towed linear array. The signal processing that was investigated formed a set of beams at a series of increasing ranges while looking in the same direction for all beams. By keeping "look direction" constant for all beams, a very high noise correlation can be achieved between beams. The results of the study proved conclusively that total target energy show a marked increase as the target came into focus, i.e., the time delay used in beamforming corresponded to a distance equal to that of the target. Audio data of the beamformed energy were produced for use in human testing. The results of human testing were very positive and showed the potential for application in more operationally useful but more complex array.

The array that this technique was now applied to was the Wide Aperture Array (WAA). Again the evaluation conditions were the same as for the TB-29 line array.

1. All noise was generated at infinity, i.e., modeled as plane waves.
    a. Two noise generators were produced: a sinusoidal wave and random component wave. The resulting noise signal is the vector sum of these two components.
    b. The noise correlation between beams can be simulated by varying the relative strengths of the sinusoidal component and the random component of the noise signal.
    c. Noise was distributed uniformly over all look directions.
2. The target signal was modeled as point source located at a finite distance and direction emitting spherical waves.
    a. Preliminary simulations have the target signal location as broadside to the line array.
3. Net signal samples from each receiver where taken at time intervals consistent with focused beamforming. The resulting samples from all of the receivers are then integrated to form a net signal.
4. Net signals for each beam were Fourier analyzed. The Fourier components between adjacent beams (in range) were subtracted and the resulting difference signal was re-generated.

Analysis of the difference signals of the simulation runs at varying target distances using the WAA show a peaking of the difference signal as the beam focuses on the target. This promising result appears very similar to findings in our earlier analysis of the TB-29 linear array. Initial analysis used a single panel of the WAA, further analysis showed that using three panels of the array yielded results even stronger than those found for the TB 29 linear array. Signal processing applied to the TB-29 array based upon those findings using actual sonar contacts yielded detections that indicated greater than double the distance in detectability. Appropriate, signal processing is now being similarly applied to the WAA using

actual sonar contacts. NSMRL sonar test software was redesigned to refine the detection measurement testing procedure. Target and background wave files are being beamform processed at NUWC. Processing is near completion.

COMMAND HISTORY
Fiscal Year 2004
Part 2

2. Special Topics as applicable

(1) Statistics on major functions:

The National Sleep Foundation has awarded the Navy Recruit Training Command the "2004 Healthy Sleep Community Award" based on research conducted by LT Jeff Dyche, MSC (NSMRL) and Nita Miller (Naval Post Graduate School). A panel of judges determined this program to be the national winner from among a dozen highly qualified applicants across the country. Darrel Drobnich had this to say about the program: "The U.S. Navy's commitment to ensuring the recruits in Great Lakes, Illinois receive the necessary amount of sleep in a quality sleep environment is to be commended. It is our hope that other Navy and DOD installations across the country will follow your example in placing a high priority on the importance of sleep and alertness in order to create healthy and productive recruits and service personnel during these times of heightened security." Darrel Drobnich, Senior Director, Government and Transportation Affairs, National Sleep Foundation, email dated 19 February 2004, to RADM Ann Rondeau, CNET.

NSMRL hosted the Submarine Escape and Rescue Working Group on 9 March 2004, with representatives from PMS395, PMS450, Electric Boat, COMSUBDEVRON 5, NAVSUBSCOL, and Portsmouth NAVSHIPYD in attendance. The purpose was to review and approve Guard Books for SEAWOLF Class, USS JIMMY CARTER, and VIRGINIA Class. NSMRL contributed significantly, with excellent contributions from CDR Wayne Horn, MSC, USN and SurgCDR Peter Benton, RN.

Captain Garry Higgins, USN, and Surgeon Commander Peter Benton, RN, returned from the Republic of Singapore following a highly successful evaluation of the Battelle Curtain's carbon dioxide scrubbing efficacy in a warm water disabled submarine scenario. The Republic of Singapore Navy conducted a 48-hour exercise involving 33 submariners isolated in the forward compartment of a submarine moored pier-side without support of ventilation or electrical power except for emergency lighting. The exercise proved conclusively that the Battelle Curtains provided substantial carbon dioxide removal, essentially doubling the survival time of the crewmembers. Temperatures rose to 95° (F) internally during the peak of the exercise and hyperthermia and dehydration were monitored closely for all personnel. The carbon dioxide level rose to 1.02% and validated CO2 scrubbing data gathered during the NSMRL DISSUB Exercise of March 2003. This exercise is the culmination of over 3 years of work by CDR Shake, MSC, USN, the BUMED (MED R&D) Liaison in Singapore, and equates to an estimated cost savings to the U.S. Navy of approximately $1M.

Dr. David Fothergill presented at the INDO-US Joint workshop on Life Sciencies. The main topic of the workshop was "Enhancing Human Performance in the Military Environment." The workshop brought together military and Department of Defense civilian physiologists

from India and the US to present research and discuss issues of common interest in the area of military human factors and environmental physiology. Dr. David Fothergill, one of the US delegates from NSMRL presented a paper on "Enhancing performance in the Undersea Environment." This workshop is the first step towards identifying areas within the life sciences where an exchange of information and collaborative efforts between the US and India may prove beneficial for both countries.

Dr. David Fothergill presented NSMRL study at the Undersea and Hyperbaric Medicine Annual Scientific Meeting, in Sydney, Australia. The paper described the open ocean trials on the effects of depth on the sound protection offered by a neoprene wetsuit. The goal of the study was to validate a previous experiment that investigated changes in wetsuit hood sound protection with depth in a small water tank in a diving chamber. Experiments were conducted in the Bahamas on a dive stage lowered to 10 and 60 fsw off the back of a dive boat. At each depth, 16 US Navy divers conducted underwater hearing tests at 8 test frequencies from 100 – 8,000 Hz while bareheaded and while wearing a 7-mm neoprene wetsuit hood. The trials showed that the differences in the pattern of wetsuit hood sound protection with depth between the ocean and chamber studies at frequencies above 1,000 Hz indicate that caution should be exercised when applying underwater human sound data collected in a small water tank in the laboratory to the open ocean environment.

NSMRL hosted the Eighth Annual Fleet Review on 20 May 04 to solicit feedback, guidance, and recommendations on the laboratory's research efforts in support of the undersea operational forces. Principal Investigators gave briefs on Submarine Watchstanding Cycles, Survival Capabilities aboard a US disabled Submarine, Submarine Atmosphere Monitoring, Anti-Terrorism/Force Protection, Situational Awareness/Navigational Issues, and Close Range Target Detection. The review panel included Captain Hanson, Chief of Staff, Submarine Group TWO; Commander Street, Bureau of Medicine and Surgery; Captain Travis Luz, CO, Naval Health Research Center; Captain Lotring, CO, Submarine Learning Center; Captain Auker, Office of Naval Research; Captain Murray, Naval Sea Systems Command, Deep Submergence; Captain Montana, Naval Operational Test and Evaluation Center; Captain Gudewicz, COMSUBPAC Medical Officer; Commander Hinman, COMSUBLANT Medical Officer; Captain Ahlers, Naval Medical Research Center; Captain Thompson, Naval Medical Combat Development Division, Newport; and LCDR Badorff, the Executive Officer of the USS SAN JUAN.

CDR Wayne Horn spoke at the National Nanotechnology Initiative (NNI) Interagency Grand Challenge Workshop. He spoke on how Submarine duty offers a close analogue to space travel. The hostile environment surrounding a spacecraft is in many ways similar to that of a submarine. Both vessels exist in pressure and temperature differentials. Astronauts and submariners live and work in an artificial atmosphere with elevated carbon dioxide levels, in a noisy environment with very limited space, and with significant limitations on diet. Absence of normal day-night cues results in living by an artificial time reference and abnormal sleeping schedules. Crews have limited communications with family, being separated by time and distance. Medical care is limited, with no surgical capability on board. Most significantly, the hostile environment poses a potential physical risk to the lives of crewmembers. The limited diagnostic and therapeutic capability onboard submarines, and similarly in spacecraft, could be significantly improved by nanotechnology products.

Improved atmospheric and biomedical monitoring are other potential capabilities that could significantly expand the horizon of space travel.

Dr. Jerry Lamb chaired the Human Systems Integration for Submarines Session at the 2004 Joint Undersea Warfare Technology Fall Conference 20-23 Sep, at the US Naval Submarine Base, New London. Other topics presented by NSMRL Researchers included Navigation: Electronic Disinformation by LT Shobe, Spatialized Audio: Technology and Applications by Dr. Santoro, and Collision Avoidance: Linking Periscope and Sonar by Mr. Russotti.

LT Katharine Shobe, MSC, USNR, took part in Presidential Classroom's National Security in a Democracy Program in Washington, D.C. from June 12-18, 2004. Selected from a competitive pool of hundreds of applicants, LT Shobe joined 15 additional volunteers to help over 320 high school juniors and seniors explore how national security is developed and protected. Sessions led by top level government, media and business officials centered on the relationships between the Department of Homeland Security, Congress, the intelligence community, the military, defense industries and the media and their roles in maintaining national security. Volunteer instructors also facilitated small group discussions on current topics, including defense industries and the economy, U.S. security and our allies, women and gays in the military and the role of media in national security.

(2) Average number of military and civilian personnel onboard in FY04.

Military Officer	7
Military Enlisted	9
Civilian Professional	7
Civilian Supporting	7
Subtotal	30
Contractors	
GeoCenters	9
IPAs	4
TOTAL	43

(3) There were no major command problems faced during the year.

COMMAND HISTORY
Fiscal Year 2004
Part 3

3. List of Supporting Documents:

(1) NSMRL Reports

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Naval Submarine Medical Research Laboratory

Groton, CT

The United States Submarine service has a long and proud tradition of developing and operating with leading edge technologies. The Naval Submarine Medical Research Laboratory (NSMRL) is a major contributor to integrating these technologies into submarine crew operations. NSMRL is DoD's Center for Undersea Biomedical Research. The laboratory's mission is to protect the health and enhance the performance of warfighters through submarine, diving and surface biomedical research solutions. Established in World War II to conduct mission critical studies in night vision, sonar sound discrimination, and personnel selection, NSMRL continues to serve the fleet by taking the lead in undersea human factors, sensory sciences and operational medicine.

Located on Submarine Base New London, Groton, CT, NSMRL researchers have access to three submarine squadrons in Submarine Group Two; the Navy Submarine School; the Naval Submarine Support Facility; Naval Undersea Medical Institute; and the Electric Boat Division of General Dynamics, which builds the nation's submarines. The laboratory is staffed by a diverse group of psychologists, audiologists, physicians, physiologists, and electrical, biomedical and nuclear engineers. Several colleges and universities are located in the same area, including the US Coast Guard Academy, Connecticut College, and the University of Connecticut.

NSMRL's accomplishments continue to be many and varied, and include scientifically based recommendations for submarine rescue procedures, submarine atmosphere limits, waivers for clinical medical conditions, advanced sonar system capabilities, diver/sonar safe distances, and symbology for visual displays.

NSMRL Scientists and Divers Touched by History

A research team of scientists and divers dove into history when they collected research data as part of a preservation project for the USS ARIZONA memorial in Pearl Harbor, HI. The team worked with Mobile Diving and Salvage Unit 1 and the National Park Service, taking underwater noise measurements of a new hydraulic tool designed to remove samples of the battleship's hull for metallurgical analysis. The research team had two jobs to do, collect underwater noise levels as part of NSMRL's two-year comprehensive in-water noise survey project and determine the on-site permissible noise exposure level for the divers. Team members also performed working dives to assist in completion of the preservation project. This is a good example of Navy scientists and divers working side-by-side with working dive lockers and other government agencies to accomplish both research data collection and provide direct fleet support.

Diving and Environmental Simulation Department

- Diving and Environmental Simulation department focuses on ways to optimize the safety and performance of Navy divers by investigating diver performance for a variety of environmental factors including sound exposure, thermal stress, and breathing gas conditions. Underwater noise can impact a diver through damage to hearing and internal organs, such as the lung and brain. Applied research includes reducing workplace hazards, providing underwater noise-protection tools and developing underwater force protection. A critical part of the program is the on-going direct fleet support regarding guidelines for operational limits due to underwater noise. These guidelines are developed directly from the basic research data collected by the laboratory.

Submarine Medicine & Survival Systems Department

- Submarine Medicine researchers focus on ways to optimize the health and job performance of undersea warfighters and reduce attrition and health impact due to psychological and physical conditions. The department includes the NAVSEA-sponsored Submarine Atmosphere Health Assessment Program.

- Survival Systems researchers conduct basic and applied research and development in the biomedical and bioengineering aspects of submarine casualties by developing equipment, procedures and guidance to optimize submarine disaster survival. The researchers serve as subject-matter experts on submarine rescue and escape for the operational fleet, policy makers and industry.

Human Performance Department

- Hearing Conservation focuses on ways to identify the early stages of noise-induced damage to the human ear to prevent noise-induced hearing loss. Current research involves the evaluation of new methods for evoking otoacoustic emissions, an objective test that is thought to be sensitive to the early stages of noise-induced hearing loss (NIHL) and a measure of susceptibility to NIHL. The team's approach is to evaluate these methods both in the laboratory for validity, reliability, and sensitivity to temporary noise-induced changes; and in the field with noise-exposed at-risk personnel for detecting the early stages of permanent noise-induced changes.

- Information Processing and Display scientists focus on ways to optimize the quality of information presented to Navy operators (e.g., officer of the deck, fire control and submarine sonar consoles) by decreasing operator workload and improving the human-machine interface. Displays that help the operator separate desired from undesired information will increase situational awareness; reduce workload; and improve the identification, classification and tracking of signals of interest.

Achievements:

- Sea Lab I undersea habitat project
- Development of the International Orange Color (Air-Sea Rescue Red)
- Disabled Submarine Escape and Rescue project
- Saturation diving and decompression tables
- Hearing conservation in noisy environments
- Safe exposure guidance for personnel in the presence of intense low and high frequency sonars.
- Studies of nitrogen narcosis
- Effects of atmospheric constituents on health and performance in enclosed environments
- Pressurized Submarine Rescue Manual
- Data-based medical qualification policies
- Farnswork lantern for screening color vision
- Underwater acoustic signal discrimination and classification